Jefferson Lab

MAGNET GROUP

EIC-Experimental Equipment

(Detector Solenoid – modifying BABAR)

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Dan Young

Probir Ghoshal

Ruben Fair

EIC-Experimental Equipment (Detector Solenoid)

Content of the talk:

1. Tasks
2. Activities so far
3. Options for the Detector
4. Solenoid specification
5. BaBar/sPHENIX Magnet
6. What Next

EIC-Experimental Equipment (Magnet)

Tasks:

This task is twofold.

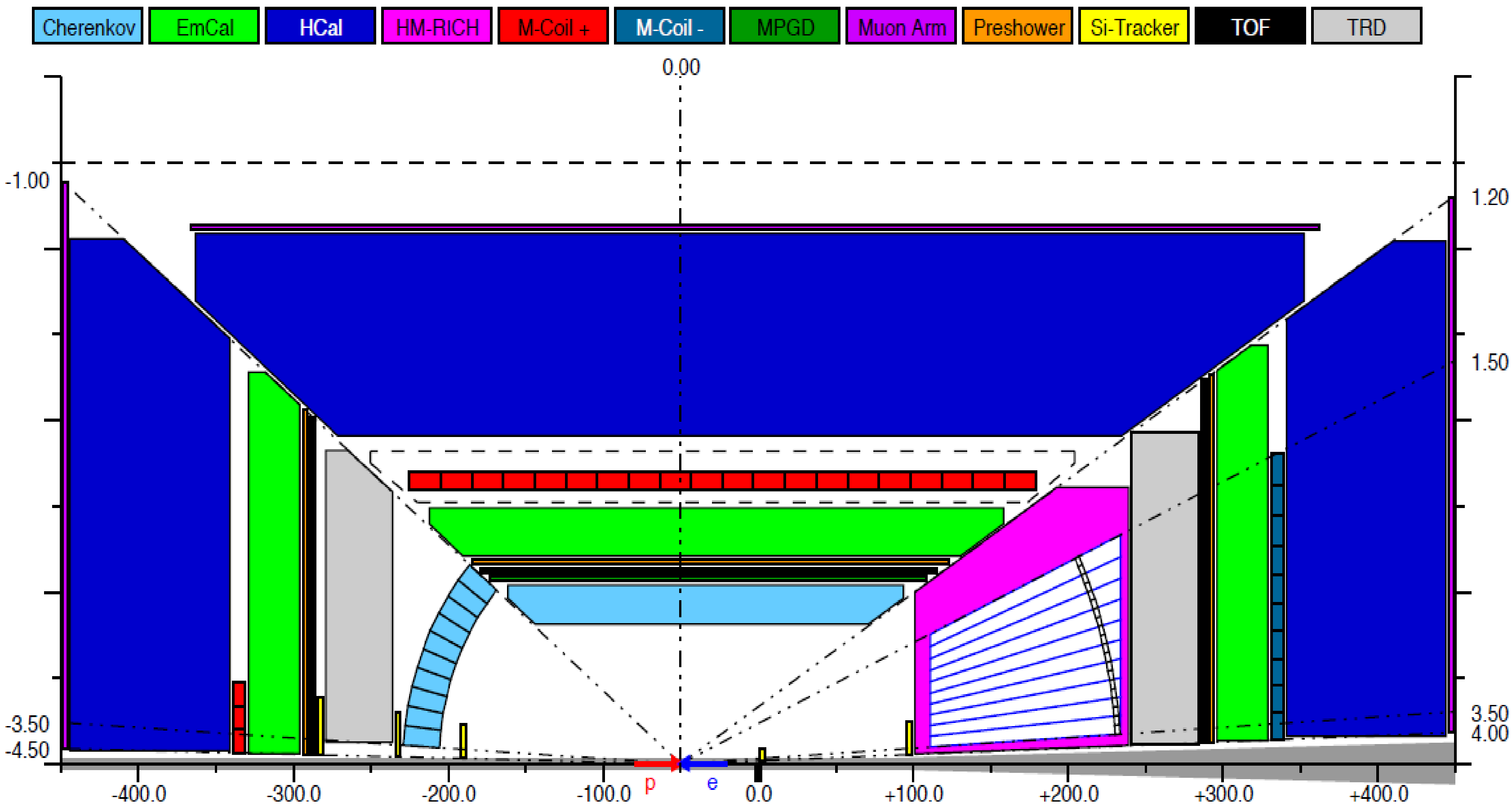
- One is to guide the EIC User Group Yellow Report activities related to space and impact and mitigation of fringe field for possible readout options of an existing solenoid, possibly somewhat modified.
- Two is to study options for further satisfying the science requirements with a potential new experimental solenoid design, with larger bore and/or higher field. The feasibility of such a SC solenoid magnet will be assessed for initial coil design, basic mechanical packaging, and component structural performance. Additional initial assessments of conductor options, quench protection, and powering scheme may be evaluated.

EIC-Experimental Equipment (Magnet)-Activities

Activities since we started this work:

- We had regular meetings with Jlab magnet group people involved in this project (Ruben Fair, Probir Ghoshal, Eric Sun, Dan Young and me).
- We had a couple of joint meetings with BNL people.
- SharePoint structure is established.
- There is a concern about the suitability of BABAR/sPHENIX magnet for EIC for next 15-20 years. As a team we are looking at the changes made in BABAR magnet for sPHENIX experiment and find out more details about the analysis done for all those changes. We have started the risk analysis for using this magnet.
- We have a OPERA (magnetic) model from BNL for sPHENIX magnet and we at JLab re-created a simplified version of this model now.
- We have started looking at the new coil design.
- Various feasible options for the detector are discussed and right now we are working with a detector model discussed in next slide.

EIC-Experimental Equipment- one of the options

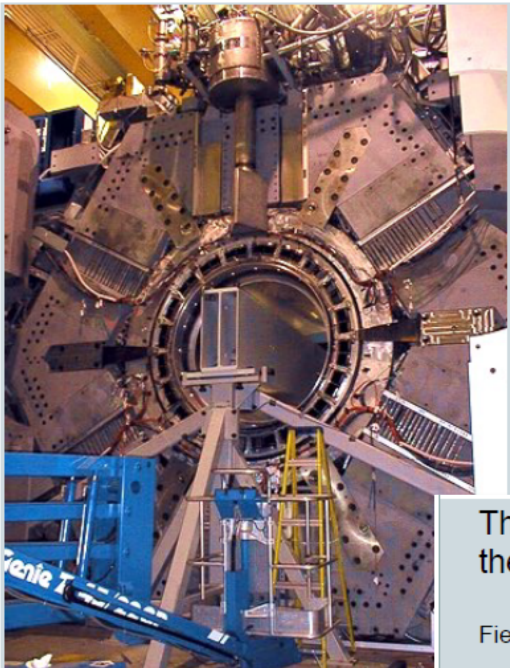


One of the possible option for further studies

EIC-Detector Magnet Specifications

- The required magnet bore is 3 m in diameter (room temperature bore). We have to base our design on this and do the design and cost estimate.
- Required central field is 3T, we have to base our design on this and do the cost estimate.
- Also do the cost estimate for 2 T field and 2.5 m bore diameter.
- The required magnetic length is 3 m, the physical length of the coil/magnet will be limited by the detectors around it.
- The coil length, conductor choice, coil winding, operating current, cooling method, etc. will be defined by the magnet design. There is no preference as such for higher/lower operating current choice.
- A complete system design needs to be done including the magnet, shielding and cryostat.
- The projectivity function ((z*by-y*bz)/sqrt(z*z+y*y)) is required for the detector solenoid in the RICH area.

The BABAR magnet



The sPHENIX superconducting solenoid magnet was formerly the BABAR magnet. It has the following characteristics:

Field Parameters:

Central Field	1.5 T Max.
Stored Energy	27 MJ

Main Coil Parameters

Mean Diameter of Current Sheet	3060 mm
Current Sheet Length	3513 mm
Number of layers	2
Operating Current	4596 A
Conductor Current Density	1.2 kA/ mm2
Inductance	2.57 H

Cryostat Parameters

Inner Diameter	2840 mm
Radial Thickness	350 mm
Total Length	3850 mm
Total Material (Al)	~ 126 mm

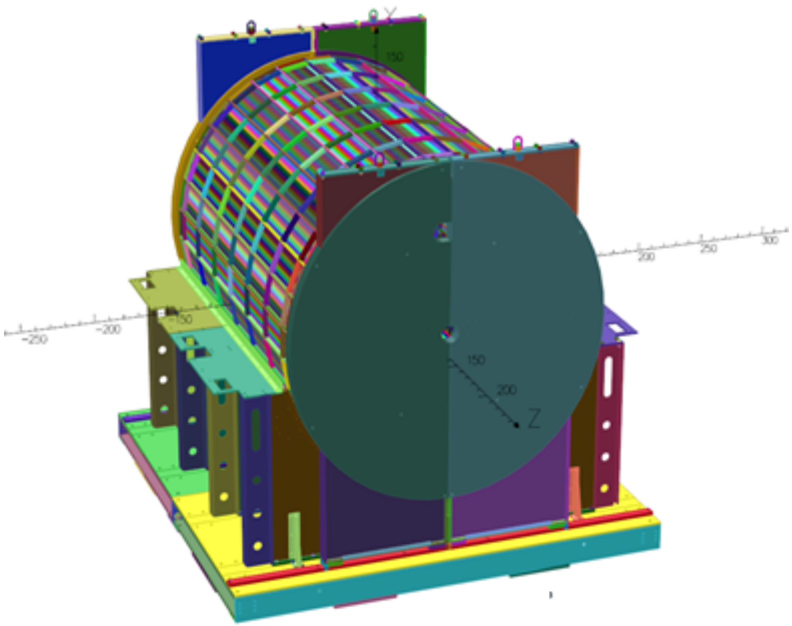
Outer HCal Steel

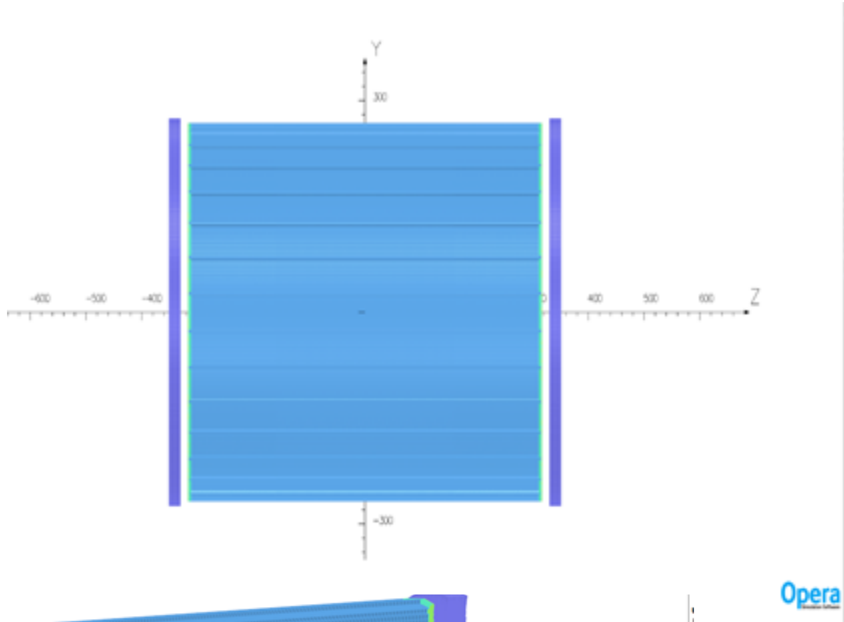
ID/OD	1780/2595 mm
Length	6010 mm
Weight	320 plates @ 1.44 metric Tons ea = 461 metric tons

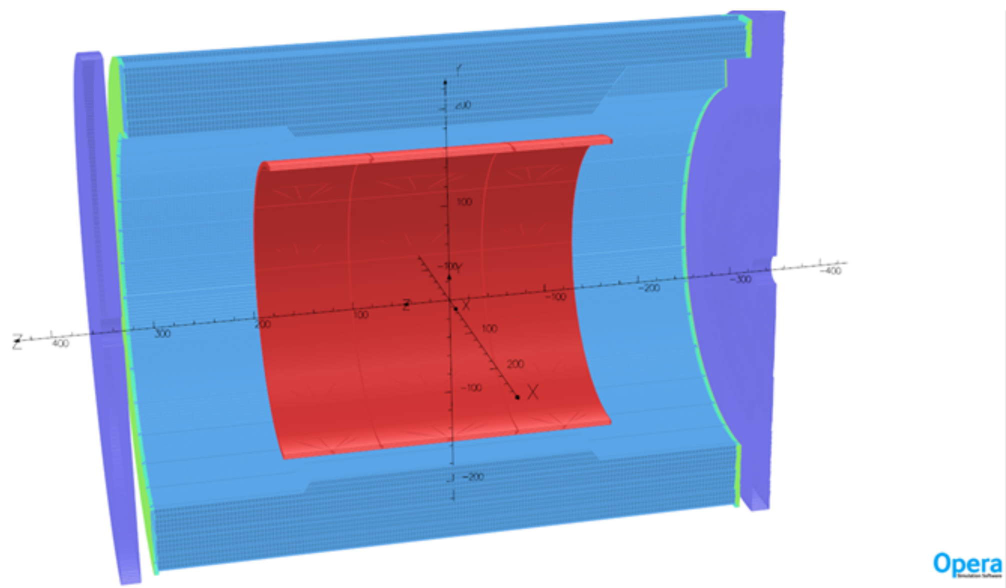
Doors (each)

ID/OD	562/5190 mm
Thickness	30 mm
Weight	50 metric tons

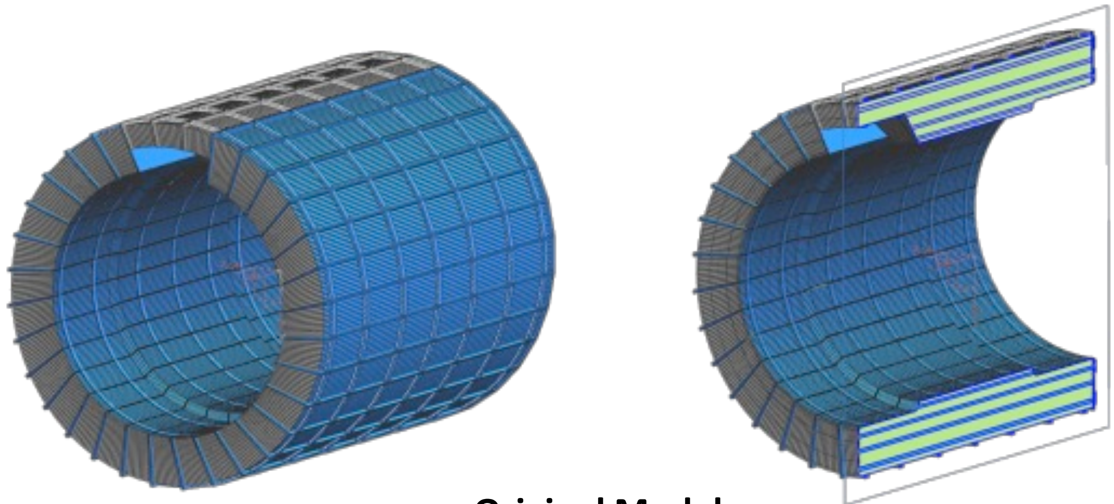
sPHENIX Magnet Model from BNL





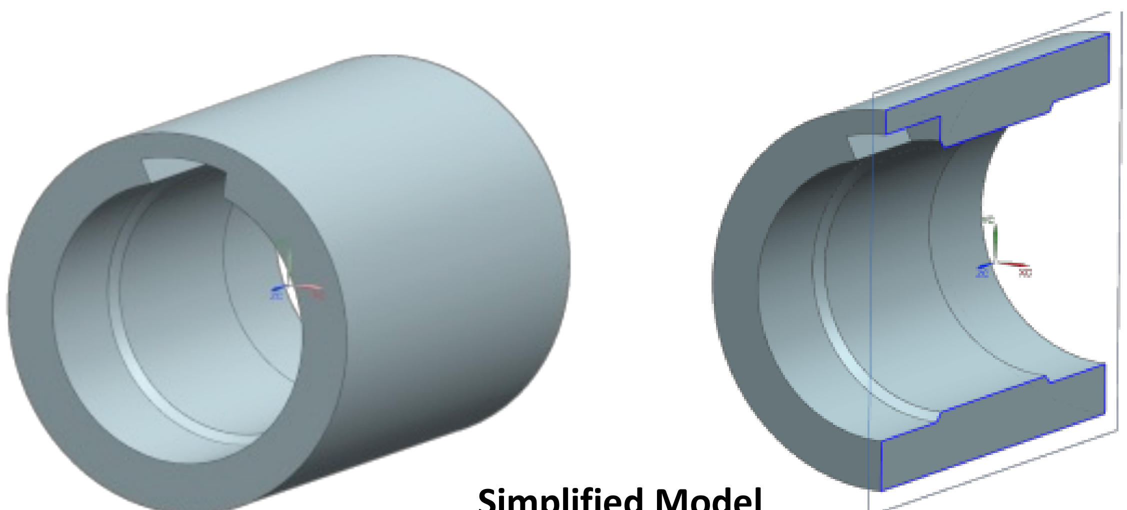


sPHENIX Magnet Model from BNL



Original Model

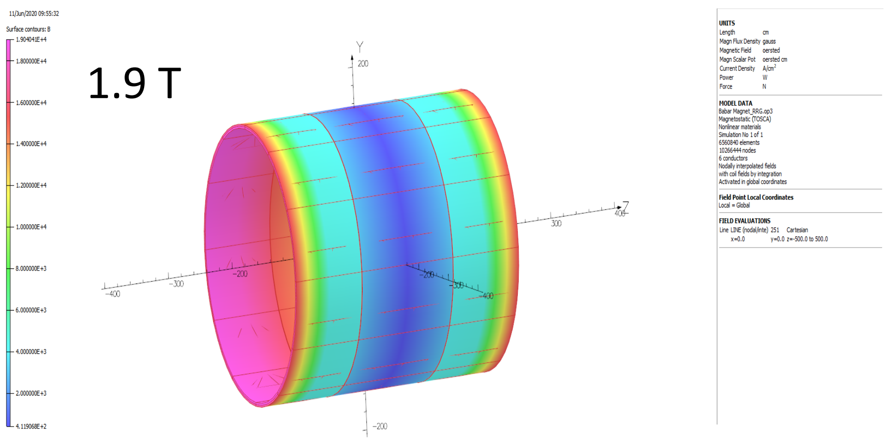
Comprised of individual solids



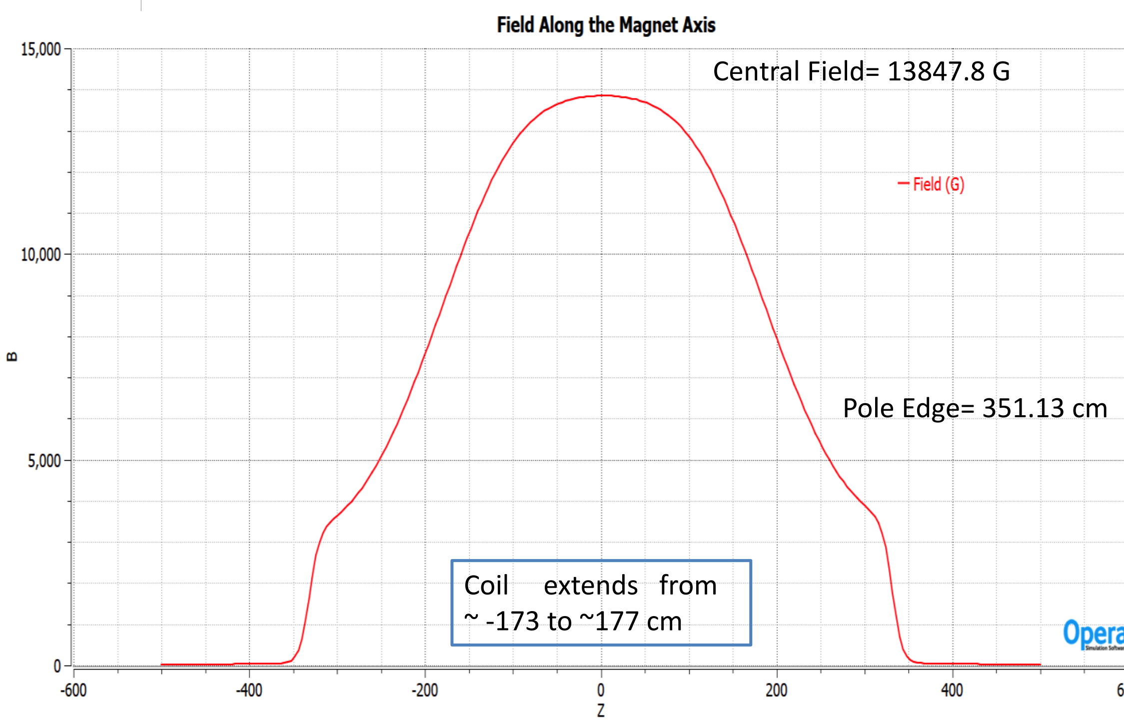
Simplified Model

Comprised of a single solid

sPHENIX Magnet Model so far



Coil field



Field along the magnet axis

Magnet Related activities-What next

Next activities for sPHENIX Magnet and for new “green-field magnet”:

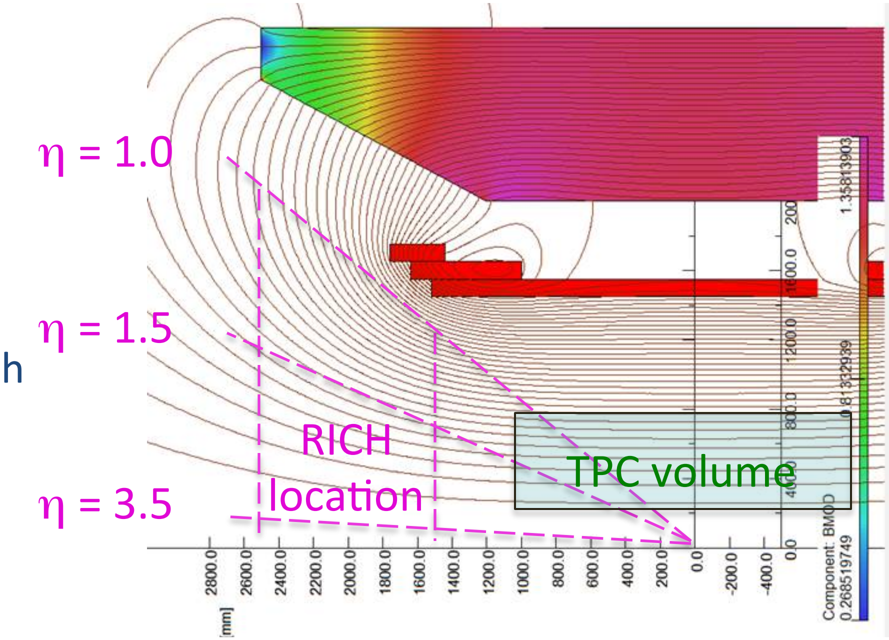
- Get the details of all the detectors in and around the solenoid
- Get the specifications/restrictions on field level/ homogeneity/ shielding/ alignment for each detector
- Compare the results from the simplified model to the original model
- Start looking at the ways to get the required field properties for sPHENIX magnet
- Start designing the green-field solenoid.

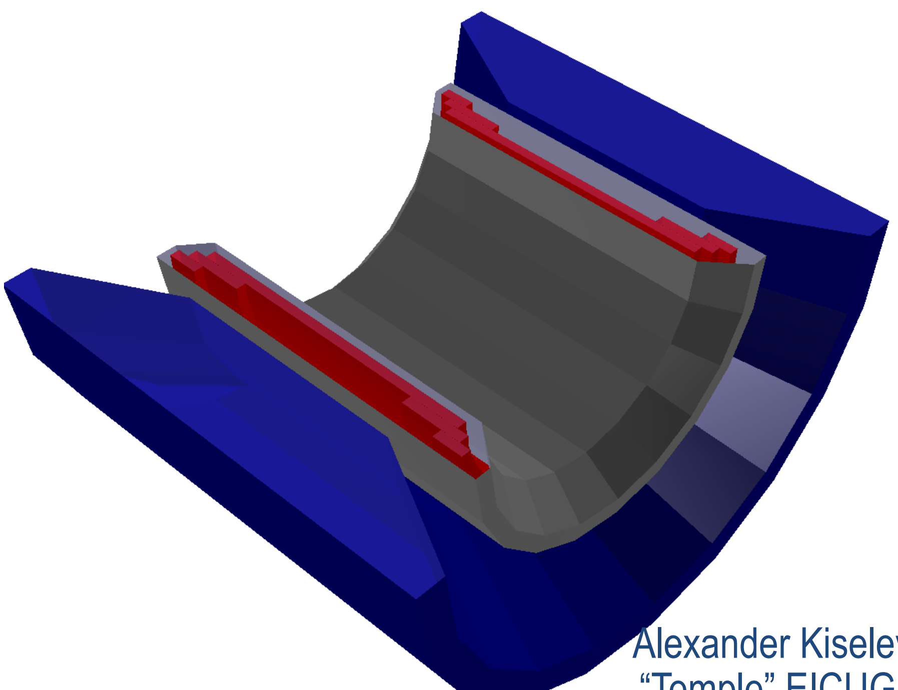
Backup slide

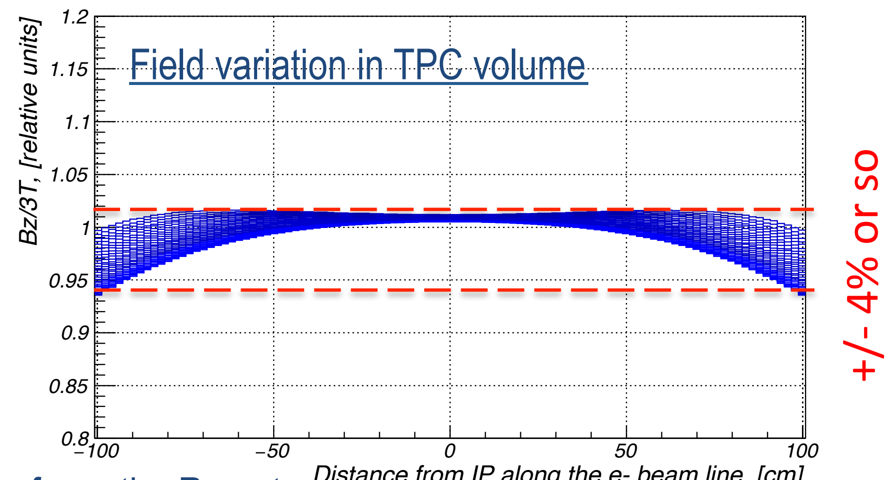
BeAST magnetic field

Goal:

- Implement in the same compact design:
  - homogeneous ~3T field in the TPC
  - hadron-track-aligned field in the RICH
- Keep it simple (no dual solenoid configuration; no reversed current coils; no flux return through HCal; no warm coils between RICH and EmCal)

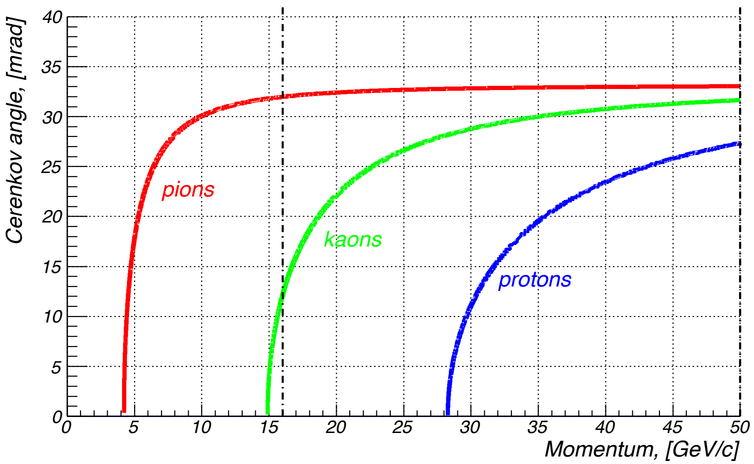






Alexander Kiselev’s slide from the Remote “Temple” EICUG YR Meeting Mar,20 2020

Will gas radiator RICH work in this field?



Consider configuration inspired by the RD6 test run:

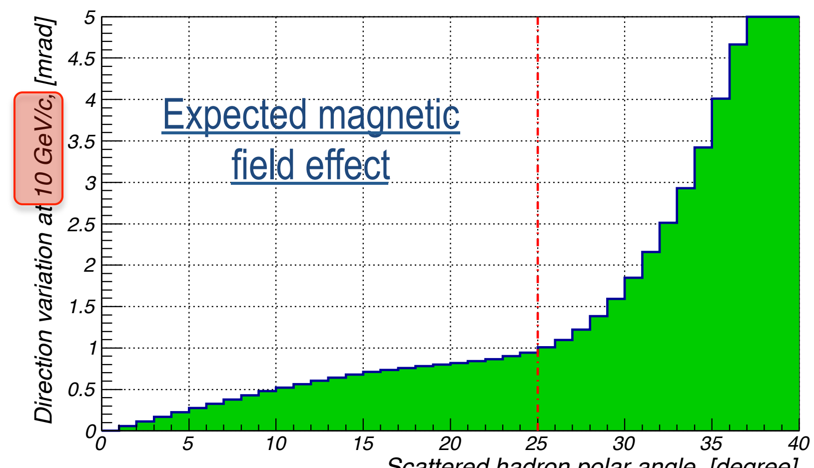
- 1m long CF_4 gas volume [1.5 .. 2.5]m from the IP
- 1m focal length; ~33mm ring radius at $\beta \sim 1$
- GEM readout; effective 2.5mm hexagonal pads
- Assume on average 12 photons per ring at $\beta \sim 1$
- Additional 300 μrad instrumental resolution

EIC R&D project

"Back-of-the-envelope" Monte-Carlo study:

- Realistic solenoid magnetic field
- Realistic tracker momentum resolution
- Cerenkov angle smearing in the field
- CsI quantum efficiency $\varepsilon(\lambda)$ dependence
- Refractive index $n(\lambda)$ variation
- Finite readout board "pixel" size

- ROOT TMVA-based output evaluation

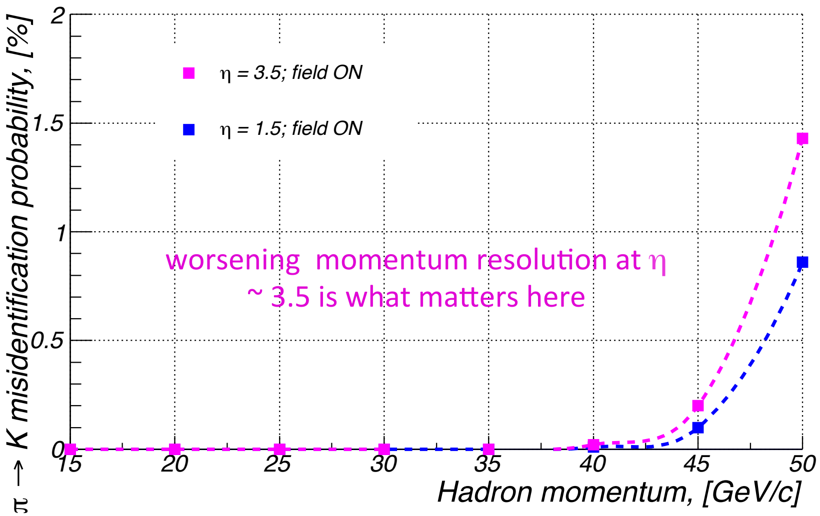


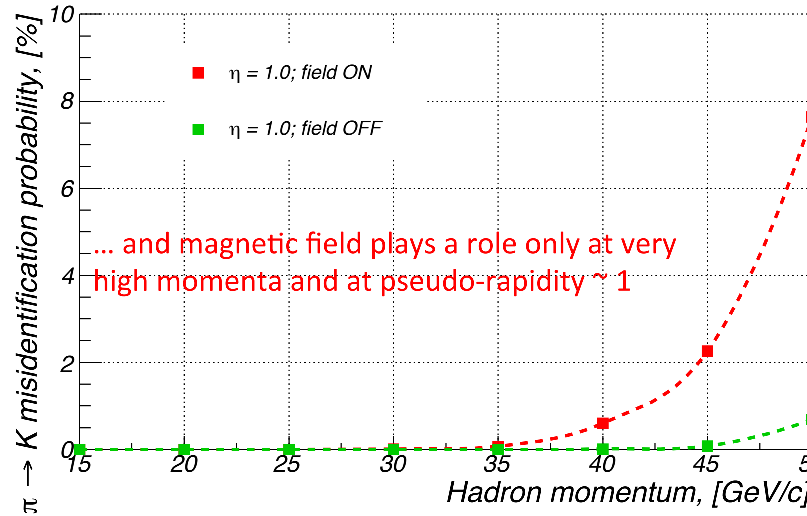
NB: this spread is in principle noticeable compared to the intrinsic single-photon angular resolution of ~1 mrad

Alexander Kiselev's slide from the Remote "Temple" EICUG YR Meeting Mar,20 2020

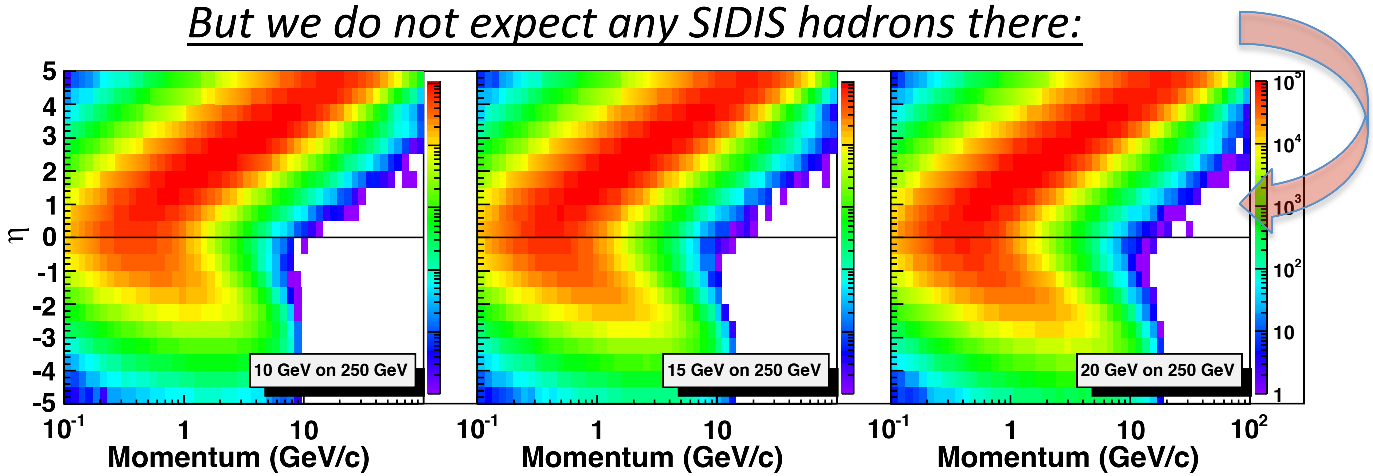
Gas radiator RICH in the magnetic field

Require 95% kaon positive identification efficiency





But we do not expect any SIDIS hadrons there:

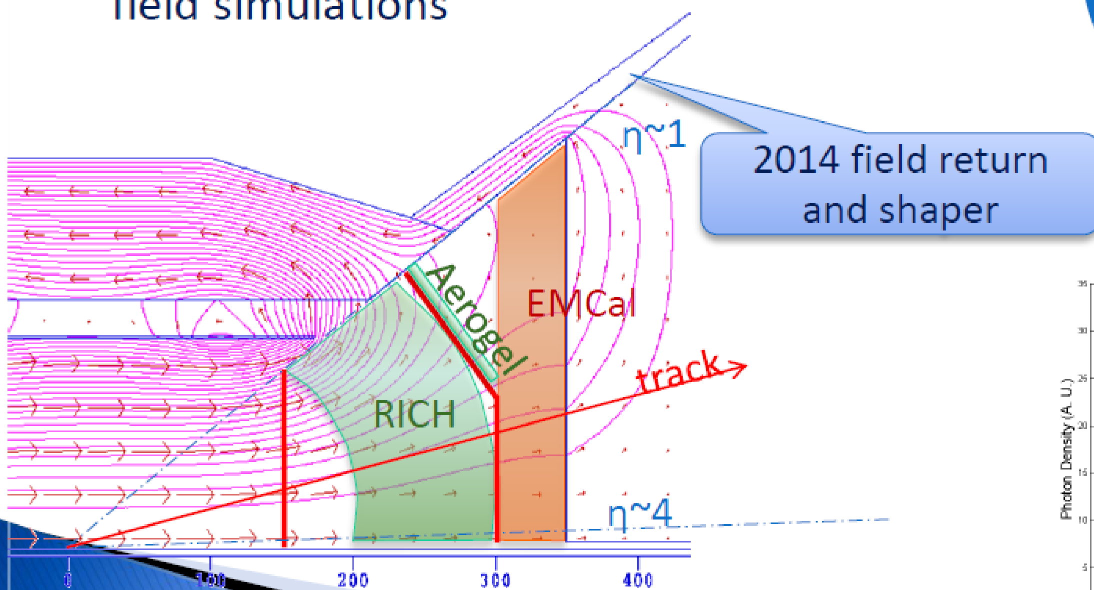


So yes, RICH with a long enough gas radiator should work just fine in this solenoid stray field

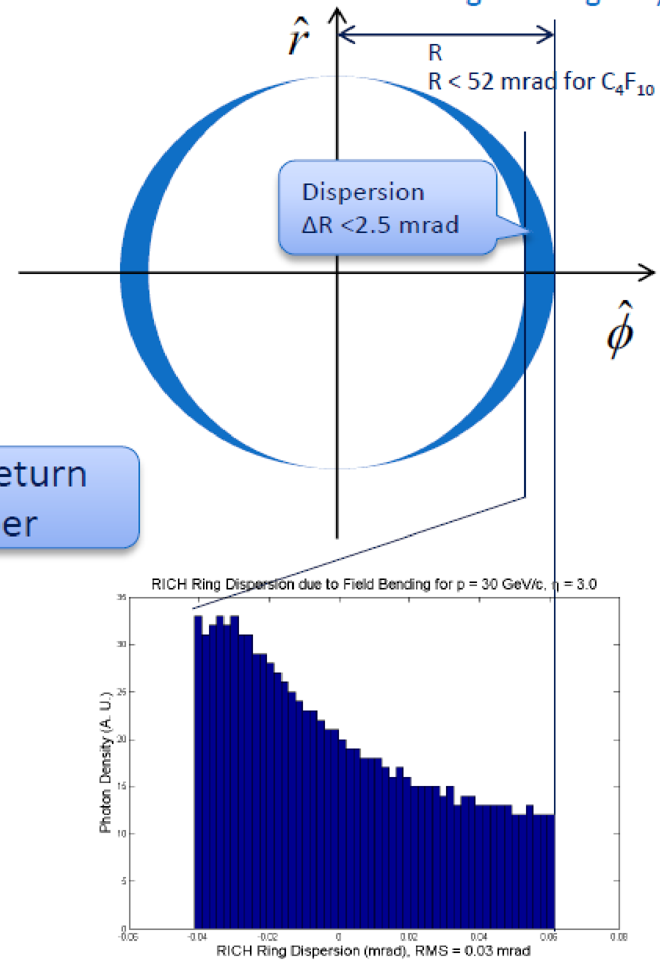
Alexander Kiselev's slide from the Remote "Temple" EICUG YR Meeting Mar,20 2020

Field effect - distortion for RICH

- Field calculated numerically with field return
- Field lines mostly parallel to tracks in the RICH volume with the yoke
- We can estimate the effect through field simulations

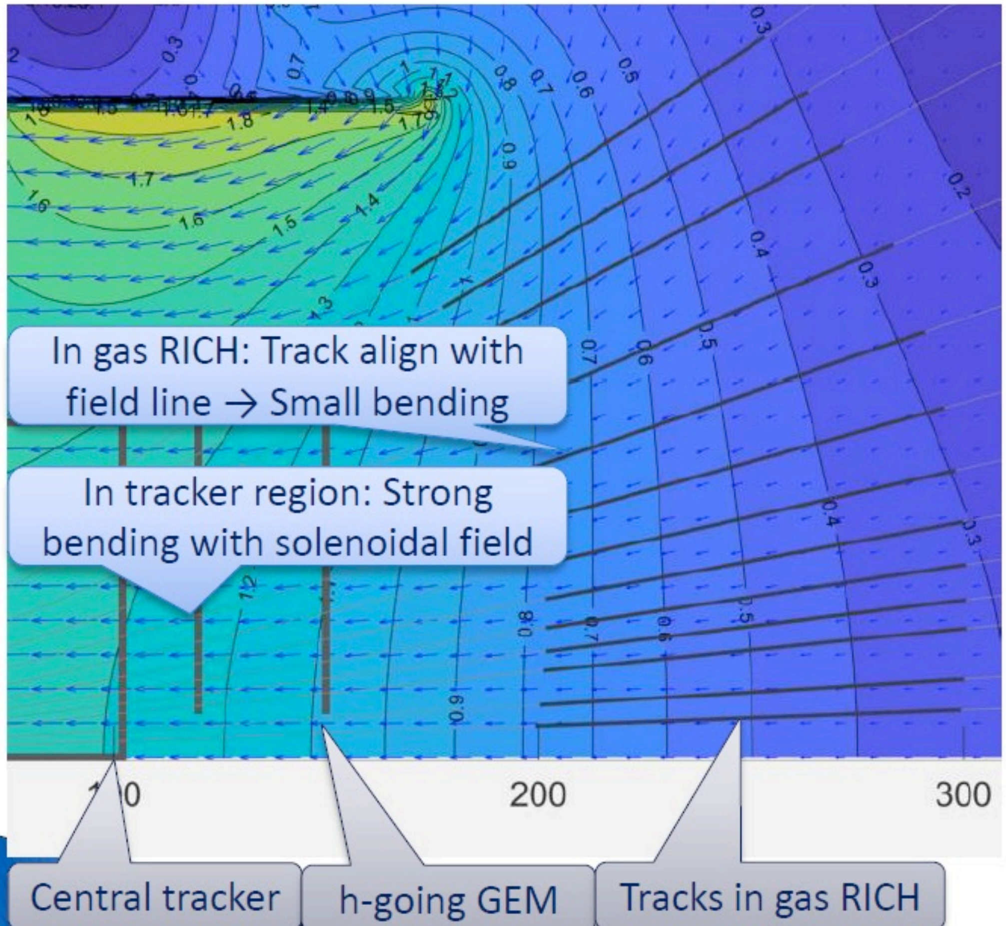


A RICH Ring :
Photon distribution due to tracking bending only



Jin Huang's slide from the Remote "Temple" EICUG YR Meeting Mar,20 2020

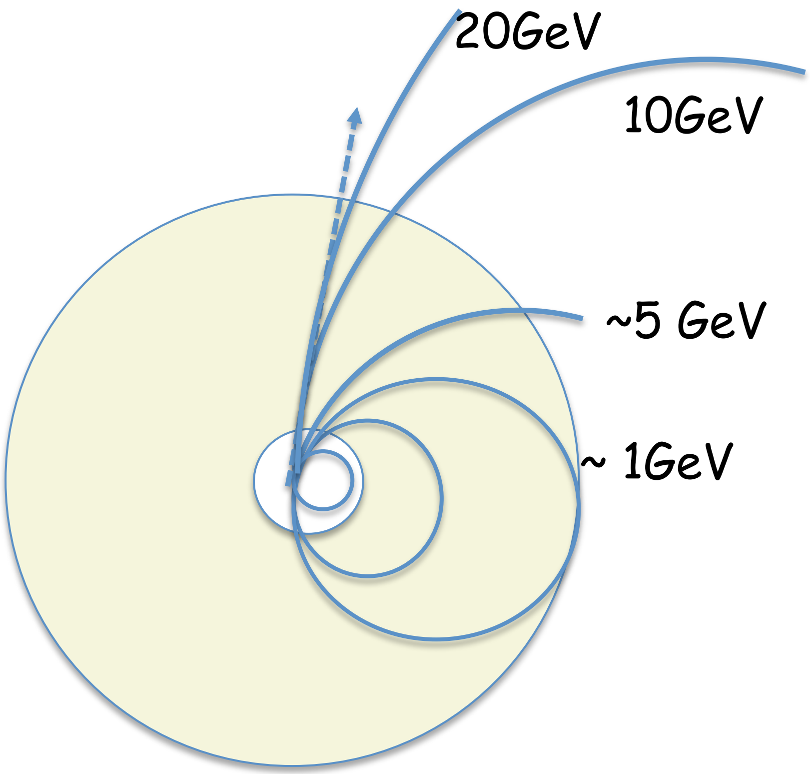
Zoom into gas RICH region

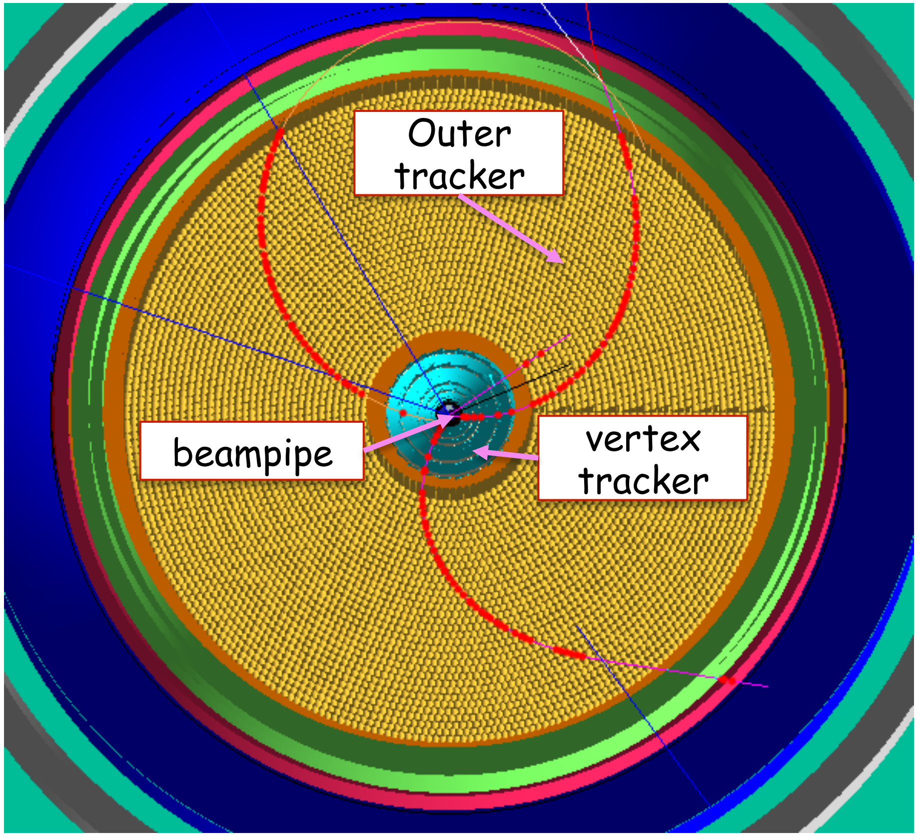


- In gas RICH region, track still align mostly along the field line → Small bending
- Larger bending field in low-eta, but max EIC collision track momentum is lower too
- More quantitative next page

Jin Huang's slide from the Remote "Temple" EICUG YR Meeting Mar,20 2020

Momentum reconstruction





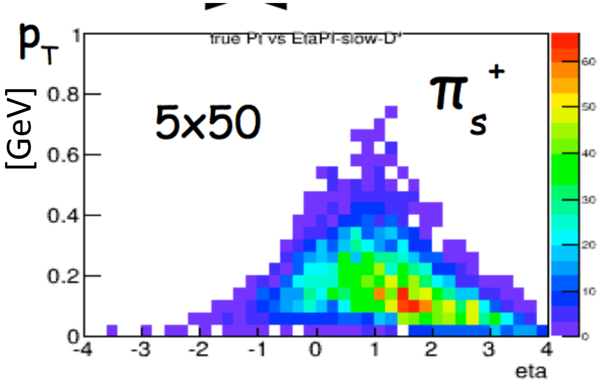
- Need high magnetic field to reconstruct bending radius: for high momentum particles, otherwise straight segment (no momentum measurements, no charge) – depends on resolution of tracker.
- Too high magnetic field: low momentum particles would curl along beampipe, without detection

Yulia Furletova's slide from the Remote "Temple" EICUG YR Meeting Mar,20 2020

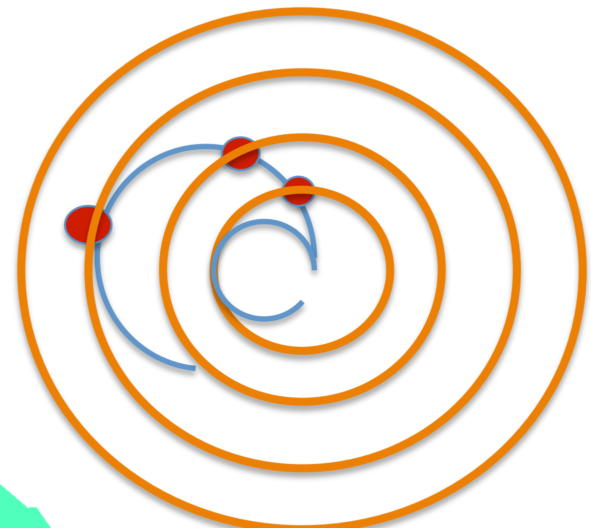
Low momentum particles

Problem of too high magnetic field:

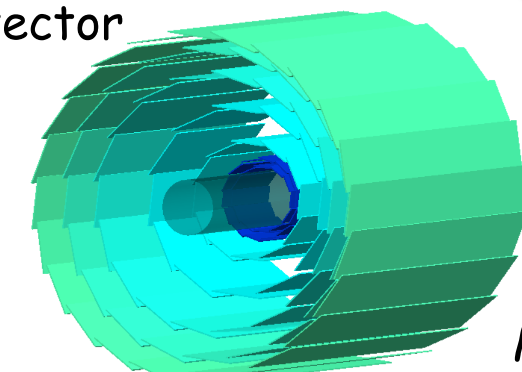
$$D^{*+} \to D^0 \pi_s^+ \to (K^- \pi^+) \pi_s^+$$



- Layered structure of vertex detectors
- For track reconstruction slow particles have to pass at least 3 layers of tracking detector



Barrel part of vertex detector



$$p_T\,[\mathrm{GeV}] = 0.3 \cdot B\,[\mathrm{T}] \cdot R\,[\mathrm{m}]$$

Beampipe: 3.2cm
Inner layer of outer tracker: 20 cm

Minimum pT possible to detect for 3T (at 6cm): ~ 30MeV

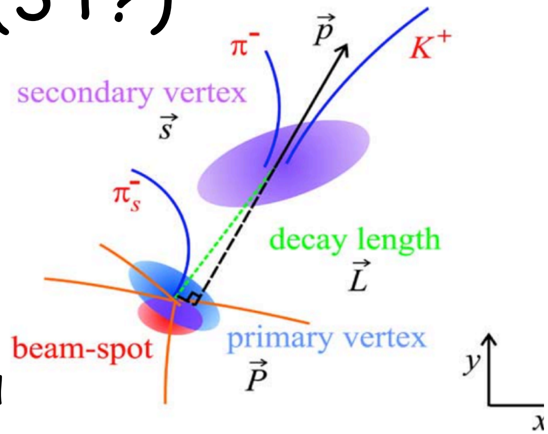
Magnetic field (3T?)

$$D^{*+} \rightarrow D^{o}\pi_s^{+}\ ,\ D^{o} \rightarrow K^{-}\pi^{+}$$

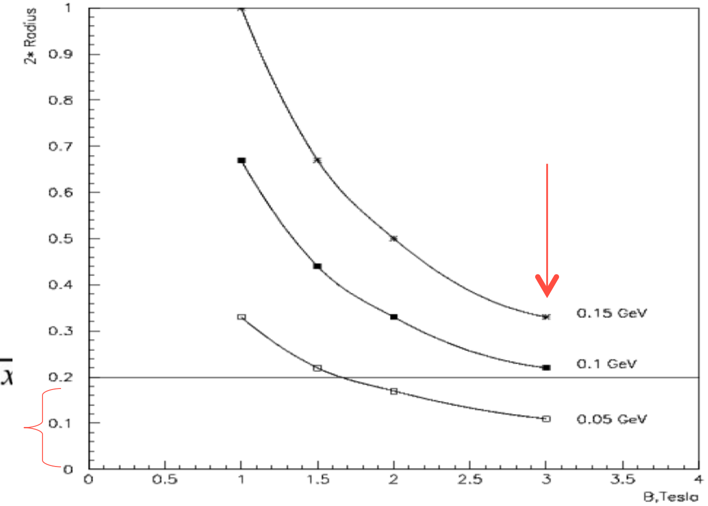
$$R(m) = \frac{P_T(GeV)}{0.3 \cdot B(T)}$$

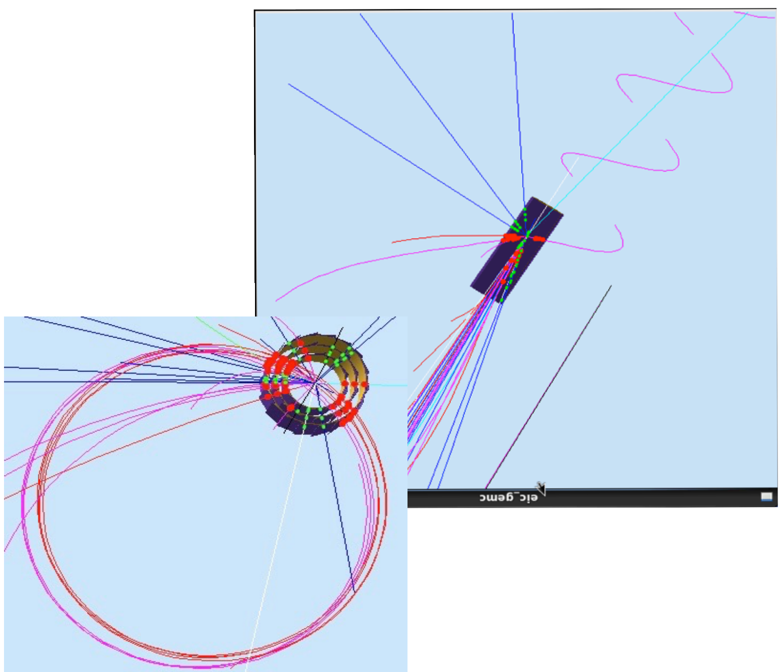
$2R > R_{out}$ (VTX)

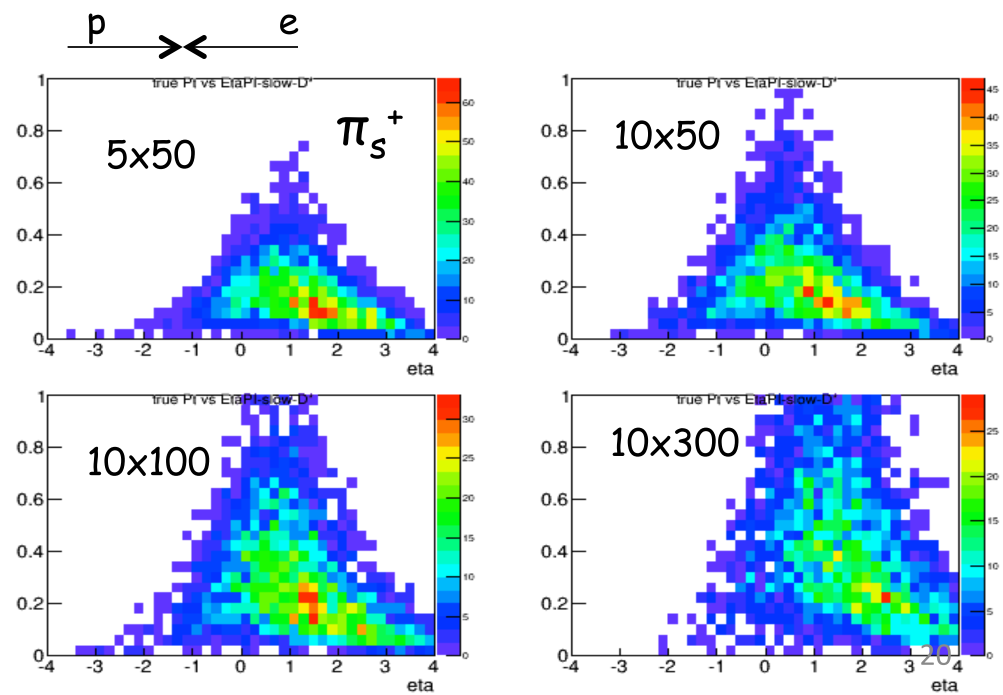
For Vertex- 20 cm in R - reserved



VTX







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